Acoustic-Trawl Surveys of Spawning Walleye Pollock (Theragra chalcogramma)

in the Shelikof Strait-Chirikof Island Region of the Gulf of Alaska

in 1980 and 1981

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by

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SUMMARY

During March 1980 and March and April 1981, acoustic-trawl surveys were conducted in the Shelikof Strait-Chirikof Island region of the Gulf of Alaska to determine the size and biological composition of a large, mainly midwater, concentration of walleye pollock (Theragra chalcogramma), composed primarily of mature adult fish. Estimates of the distribution, biomass and age composition of the off-bottom component of the stock were determined from echo integrator and midwater trawl data collected during a single survey in 1980 and three surveys in 1981. During both years, bottom trawl sam es were used to compare the biological composition of the near-bottom component of the stock (not included in the acoustic estimates of abundance1 with that of the main midwater concentration of fish.

The point estimate of pollock biomass determined from the 1980 acoustic survey, which was apparently conducted just after the peak of spawning, was 709,000 mt. In 1981, biomass point estimates determined from surveys conducted prior to, during, and after the peak spawning period, were 801,000, 576,000 and 558,000 mt. The 1980 and 1981 estimates were substantially larger than would have been expected from previous information. The biomass estimates were determined using a target strength value of -31.3 dB/kg obtained from Traynor and Williamson (1982). Although more information is needed on the accuracy of this value, and on other factors affecting the biomass estimates, the surveys' results have reemphasiied the need to obtain new estimates of the abundance and potential yield of Gulf of Alaska-pollock stocks. They also suggest that it may be possible to use acoustic-trawl surveys of spawning concentrations to significantly improve abundance estimates currently used by management.

The walleye pollock (Theragra chalcogramma) is a semi-pelagic gadoid fish which occurs on the continental shelf and upper slope throughout the North Pacific Ocean north of 40° north latitude. The biology of pollock resources off Alaska is discussed by Hughes and Hirschhorn (1979) and Smith (1981). In the Gulf of Alaska, the annual catch of pollock prior to 1972 was usually less than 10,000 mt. Since that time the catch, which until 1981 was taken almost exclusively by foreign trawlers, has increased approximately 10-fold; the average annual catch for 1977-1980 was 109,000 mt (Balsiger and Alton, 1981). In 1981 and 1982, a substantial U.S.-foreign joint venture pollock fishery, which has targeted on the spawning stock discussed in this report, was developed near Kodiak Island. As shown by both the fisheries (e.g., see Fig. 1) and a series of bottom trawl surveys during 1973-1978 (Alton, 1981a), pollock are most abundant in the western part of the Gulf. Usually over 95% of the catch has been taken in the Shumagin and Chirikof-Kodiak regulatory areas.

New estimates of the biomass and maximum sustainable yield (MSY) of Gulf of Alaska pollock are needed. The current estimate of equilibrium yield, which is equal to the MSY estimate, is 166,000 mt; 57,000 mt for the Shumagin area, 95,000 mt for the Chirikof-Kodiak area, and 14,000 mt for the Yakutat-Southeastern area (Balsiger and Alton, 1981). This estimate was determined from the Gulland (1970) equation using a natural mortality rate (M) of 0.4 and a first order approximation of biomass of 1,055,000 mt (NPFMC, 1981). Biomass was conservatively estimated from bottom trawl surveys using the "area-swept" method (Baranov, 1918; Alverson and Pereyra, 1969) and a catchability coefficient of 1.0. Stock size estimates based on virtual population analysis are not yet available and, despite significant problems

YAKUTAT -
SOUTHEASTERN

(4,631 mt)

147° W

CHIRIKOF · KODIAK

(61,718 mt)

54° 30' N

SHUMAGIN

(46,647 mt)

170° W   159° W

60 00N

50 00N

40 00N

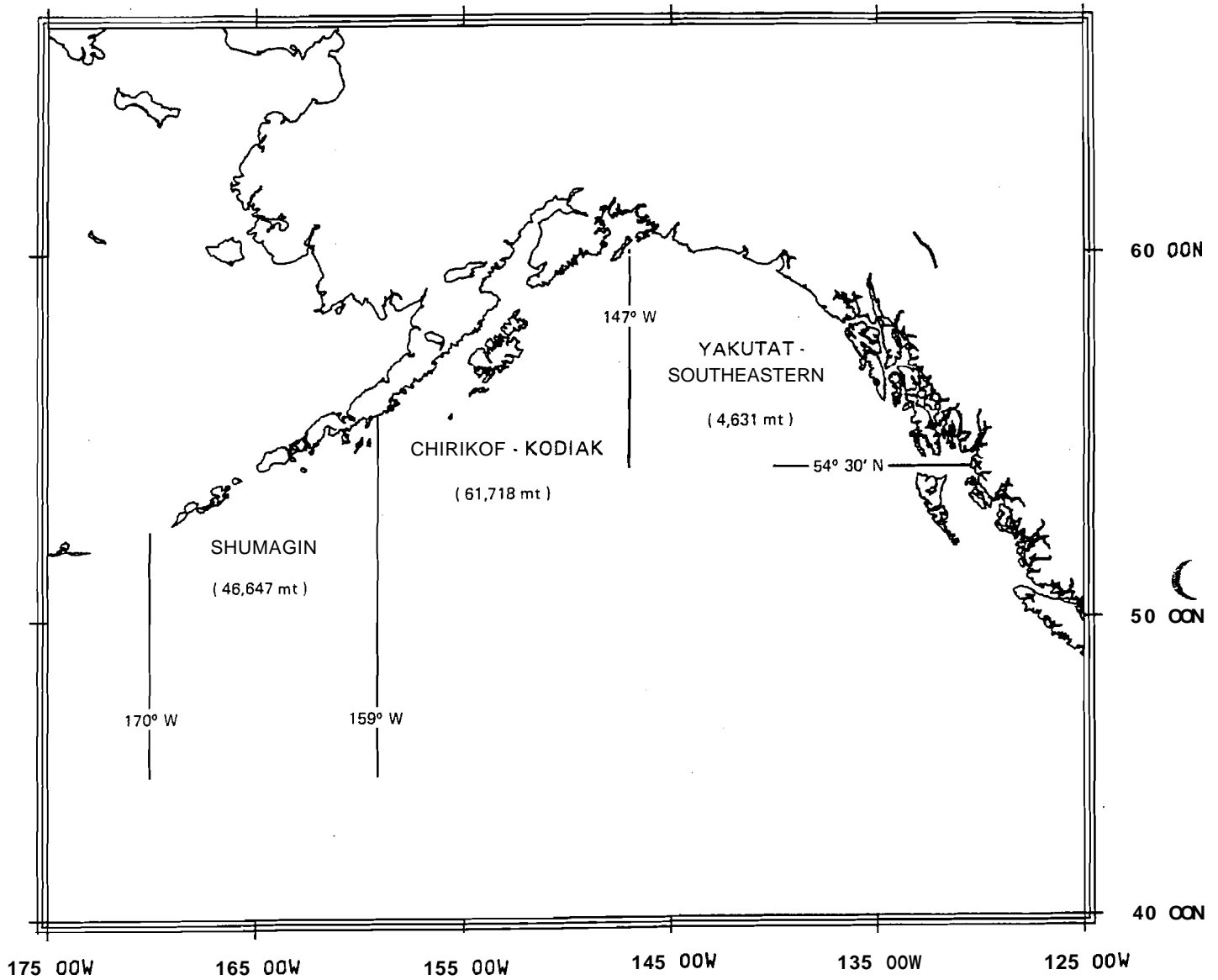175 00W   165 00W   155 00W   145 00W   135 00W   125 00W

Fig. 1.--Regulatory areas of the Gulf of Alaska showing total foreign
pollock catch in 1980 (from Balsiger and Alton, 1981).

in estimating fishing effort, annual assessments rely on CPUE and size-age composition data from selected foreign trawl fleets.

Development of a fishery independent method (other than bottom trawl surveys) to provide new pollock biomass estimates for the Gulf of Alaska, as well as to improve methods used to monitor changes in stock size and recruitment has been recommended. But until 1980, there was little indication that this might be feasible. Prior to 1980, there was limited application of acoustic and midwater trawl sampling in the Gulf of Alaska, and it was done mainly in the summer, a time of year when an impractical amount of survey effort would probably be required to provide reliable estimates of pollock abundance (Nelson et al, 1981). The discovery in 1980 of an unusually large off-bottom layer of spawning pollock in the Shelikof Strait-Chirikof Island region west of Kodiak Island, and the subsequent survey efforts described herein, have provided some new insight into the possible size of the pollock resource which suggests that acoustic-trawl surveys (and, eventually, ichthyoplankton surveys) can play an important role in improving the data base required for management.

The Shelikof Strait concentration of pollock echo sign was unexpectedly encountered during a March 1980 bottom trawl survey being conducted by the Northwest and Alaska Fisheries Center. After preliminary echo sounder obser- vations and sampling had identified its composition and approximate size, arrangements were quickly made to provide the personnel and equipment necessary to conduct a quantitative acoustic survey. The survey was sub- sequently completed in early April. Based on its success, a series of surveys was carried out in 1981. The purpose of the surveys was to obtain acoustic estimates of the biomass and distribution of the off-bottom pollock concen- tration in the Shelikof Strait-Chirikof Island region, and to obtain estimates

of the sex, size, age and maturity composition of pollock from midwater and bottom trawl sampling. Ichthyoplankton and environmental (CTD) sampling was conducted during each survey, but detailed results of this work are not yet available.

METHODS

The surveys were conducted on the NOAA research vessel MILLER FREEMAN, a 66 m, 2200 hp stern trawler. The 1980 survey period was April 2-14. In 1981, surveys were carried out during March 2-19, March 24-29, and April 4-10. The geographic area covered during each survey is shown in Fig. 2. Depths over most of the survey region are between 110 fm (201 m) and 160 fm (292 m); the maximum depth is approximately 175 fm (320 m). The bottom rises steeply inside of the 100 fm (183 m) contour on each side of the Strait, and the distance between the 100 fm (183 m) and 50 fm (91 m) contours is usually only 3 to 4 n.mi.

Survey Design

As shown in Fig. 2, echo integrator data were collected on tracklines consisting of zig-zag transects which normally ran across Shelikof Strait. The transects ended between the 50 fm (91 m) and 100 fm (183 m) bottom contours on both sides of the Strait. Usually, very little echo sign was detected inside the 90 fm (165 m) contour. The surveys were conducted 24 hours per day because significant diel changes in the vertical distribution and detectability of the pollock were not observed.

Midwater trawl hauls were made during each survey to determine the species composition of the echo sign and, especially, to obtain information on variation in pollock size/age and maturity composition within the survey area. The location of the trawl stations was based on both the observed distribution of echo sign and the need to determine possible geographic differences in
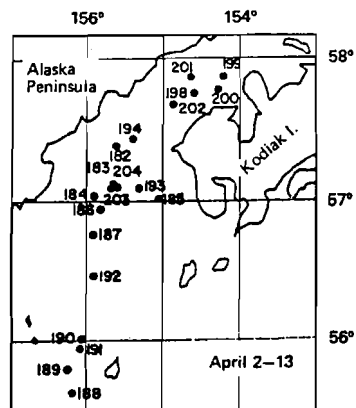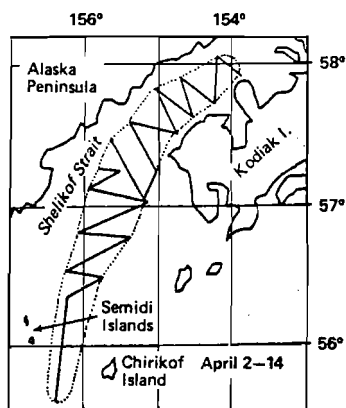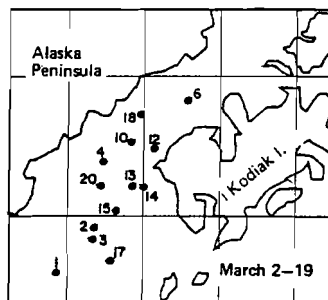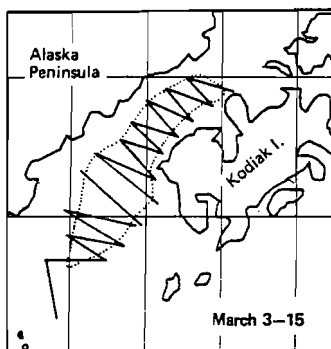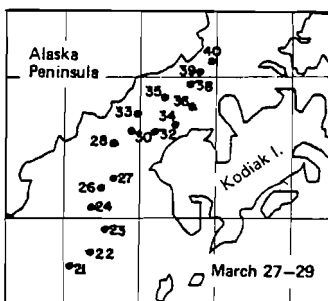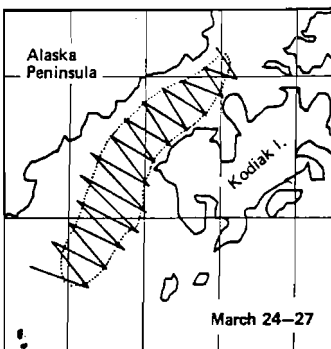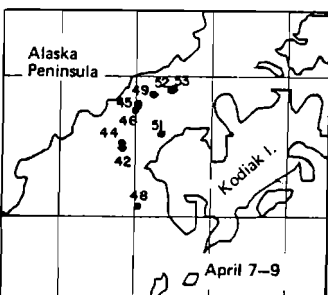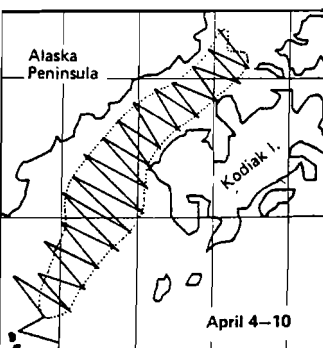
Fig. 2.--Acoustic survey tracklines, midwater trawl stations, and approximate areas of the off-bottom pollock concentrations during the 1980 and 1981 surveys.

the biological composition of pollock. Trawl hauls varied in duration; usually the trawl was retrieved as soon as the netsounder indicated that a quantity of fish sufficient for sampling purposes had been captured. Bottom trawl hauls were made during each survey in 1981 to provide data for comparisons of the size composition and other biological characteristics of off-bottom pollock with those of pollock near bottom that were not included in estimates of abundance derived from the acoustic data. Bottom trawl data were also available from the March 1980 survey.

Acoustic Data Collection and Analysis

For both years, estimates of the abundance of the off-bottom component of the pollock stock were derived from digital echo integrator data collected using 38 kHz echo sounders (Table 1).[1] The echo sounder transducers were mounted in V-fins towed at depths of 5 m and 20 m in 1980 and 1981, respectively. Average vessel speed on survey transects was about 9 knots. In 1980, the data were collected on a cassette tape recorder and later processed in the laboratory on a computerized echo integration system described by Traynor and Nelson (1981). A portable echo integrator system (Biosonics, Inc. Model 120) was used on the vessel in 1981 and initial analysis of the integrator outputs was done at sea using a Radio Shack TRS 80 Model I minicomputer. Echo integrator outputs were obtained for each 20 m depth stratum between the transducer and 3 m above bottom (with appropriate corrections for strata which included the bottom). The outputs were obtained at 1 minute intervals along survey transects in 1980 and at 5 minute intervals during the 1981 surveys. The echo sounder systems were calibrated using standard calibration methods described by Dark et al (1980) and Traynor and Nelson (1981). Calibration data for the acoustic systems are shown in Table 1.

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[1] Reference to trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

Table 1 Basic echo sounder system specifications and calibration data.

System Specifications

	Survey Year 1980	Survey Year 1981
Frequency	38 kHz	38 kHz
Transducer Dim.	23 cm (circ)	44 cm (circ)
Beam width (-3dB)	12°	6°
Transmitter	Simrad EK-38A	Biosonics model 101
Receiver	Simrad EK 38A	Biosonics model 101
Nominal power out	1 kw	1 kw
Nominal pulse length	0.6 ms	0.6 ms
Pulse rep rate	24/48/96 per minute	60 per minute
Echo recorder	Simrad EK-38A	EPC model 1600
Total V-fin	Braincon (2 ft)	EDO-Western del 6215 (4-ft)

Calibration Data

	Survey Year 1980	Survey Year 1981
Calibration date	12/10/78	0/12/81
Source Level (dB//upa)	220 5	214 6
Transmitting sensitivity (dBupa/V)	-172.7	-170.5
Receiving sensitivity (dBV/upa)	-173.8	-175.3

During each survey, system gain was monitored using a calibration oscillator. A test voltage input to the receiver was integrated for each of a selected set of depth intervals. Normally this was done at the start of each transect. Each test integration ($\bar{I}_t$) value was then compared to an initial ($\bar{I}_o$) value obtained at the start of the survey. The ratio of the initial and test values, defined as $K_s = \bar{I}_o / \bar{I}_t$, was then used as a constant multiplier during echo integration scaling.

Echo integrator outputs were scaled to estimates of fish density using the relation:

$$\bar{\rho}_{ij} = \bar{I}_{ij} K_s (AB_j)^{-1}$$

where $\hat{\rho}_{ij}$ is the estimated density (kg/m^3) for output i in depth stratum j, $\bar{I}$ is the average squared echo voltage, K_s is the correction factor for changes in system gain, A is a constant which is a function of all range independent terms (including target strength, i.e., mean scattering cross section) in the echo integrator equation, and B is a constant which is a function of the range dependent terms in the integrator equation and corrects the time-varied-gain (TVG) of the system to $20 \log_{10}R + 2\alpha R$. The procedures used for estimating A and B are described by Traynor and Nelson (1981). The estimate of target strength used in determining density was -31.3 dB/kg. This value was based on dual beam estimates for pollock in the Bering Sea reported by Traynor and Williamson (1982) and was obtained by averaging day and night measurements.

Surface area related estimates of biomass density ($kg/1000\ m^2$) were obtained by appropriate summation of the estimates of ρ_{ij}. As indicated previously, the estimates were obtained for 1 minute and 5 minute .intervals in 1980 and 1981, respectively. Estimates of biomass were calculated by multiplying mean density by geographic area. Boundaries for extrapolation

were determined from examination of the geographic distribution of densities and echograms. Because of the uniformity of the echo sign, and the absence of significant quantities of species other than pollock in the midwater trawl catches, analysis of the species composition of the catches was not critical to identifying the echo sign and delineating the area inhabited by pollock.

As expected, during each survey there was significant serial correlation between successive density estimates along the survey transects. Consequently, as suggested by Shotton and Dowd (1975) and Williamson (1982), estimates of sampling error were calculated using cluster sampling variance estimation methods. Each survey transect was treated as a cluster of density observations (the biomass per unit surface area estimates obtained at either 1 minute or 5 minute intervals were the individual observations). The variance of the mean density was calculated using the equation presented by Williamson (1982) from Kish (1965). The variance of each biomass estimate was calculated as: $\text{Var}(\overset{n}{B}) = A^2 \text{Var}(\bar{d})$, where A is the appropriate estimate of surface area and $\bar{d}$ is mean density. The associated confidence interval was calculated as $\overset{n}{B} \pm 1.96 \text{Var}(\overset{n}{B})$.

Trawl Sampling and Biological Data Collection and Analysis

Midwater sampling was done with a Diamond 1000 trawl (Fig. 3). In 1981, the codend had a 1.5 in (3.8 cm) mesh liner; no codend liner was used in the 1980 survey. In 1980, the trawl was fished with 45 fm (83 m) dandylines (sweeplines) and 7 X 10 ft (2.1 X 3.0 m) steel V doors. In 1981, 30 fm (55 m) dandylines and 6 X 9 ft (1.8 X 2.7 m) steel V doors were used. The trawl was positioned using a cable netsounder. Average trawling speed was approximately 3.5-4.0 knots. Netsounder echograms indicated the vertical mouth opening of the trawl ranged from 13 to 20 m. Most bottom trawl hauls

DIAMOND TRAWL

4 Wing/body panels

Fig. 3.--Diagram of Diamond 1000 midwater trawl.

were made with an 83/112 Eastern trawl described by Wathne (1977). It was equipped with a 1.5 in (3.8 cm) codend liner and had a vertical mouth opening of approximately 2 m.

The processing of trawl catches to obtain species composition and biological data was essentially the same for all surveys. For each haul, the total weight and number was estimated for each species. These estimates were obtained either by sorting the entire catch, or, if it exceeded about 2,500 lbs, by Sampling it using the technique described by Hughes (1976). Length frequency samples for pollock (∿200 fish per haul) and other species were collected using a method similar to that described by May and Hodder (1966). Fork lengths of pollock were measured to the nearest whole centimeter. A length frequency, by sex, was obtained for each pollock catch (most fish less than 20 cm were not sexed). Specimens in the pollock length frequency samples were used to obtain maturity data and otoliths. The maturity of pollock was macroscopically examined in the field. Estimates of maturity composition were obtained by classifying the appearance of the gonads using a 5-point scale (Appendix). Pollock otoliths were usually collected from at least 100 fish in the length sample.

The relative length composition, by sex, of the off bottom component of the pollock stock was estimated for each survey by weighting individual midwater trawl haul length frequency samples and combining them over the entire survey area. Each weighting factor was the average of several pol-lock density (biomass per unit surface area) estimates obtained at, or immediately adjacent to, the haul locations.

The age composition of off-bottom pollock was estimated using the weighted midwater trawl length composition obtained during the acoustic survey and an age-length key based on otolith samples. Ages were determined

as described by LaLanne (1979). In 1980, otoliths were not collected from midwater trawl catches and the age data were from otolith samples collected on a March 1980 bottom trawl survey of the area. Estimates of biomass, by age, of off-bottom pollock were calculated using the age and length composition data and a length-weight relationship.

RESULTS

During the 1980 acoustic survey, echo integrator data were collected along a 425 nautical mile trackline and 20 midwater trawl hauls were completed (Fig. 2). Bottom trawl catch data for 1980 were available from 57 hauls made throughout the survey area during March 12-28. In 1981, the trackline distances for each of the three acoustic surveys were, respectively, 675, 612, and 763 n.mi. Thirty eight midwater trawl hauls and 13 bottom trawl hauls were made during the 1981 surveys.

Distribution and Abundance

During both years, pollock echo sign was detected throughout most of the survey region at bottom depths greater than 90 fm (165 m). There was a marked absence of echo sign at shallower depths. The fish were typically present as a dense scattering layer, often contiguous or nearly contiguous with the bottom (Fig. 4). The vertical extent of the layer ranged from approximately 10 fm (18 m) to 40 fm (73 m). Little sign was observed in the upper part of the water column, i.e., above 50 fm (91 m) from the bottom. There was significant variation in the density and vertical extent of the layer of echo sign. However, its continuity and relatively uniform appearance were unusually pronounced, and this was reflected in the small quantities of species other than pollock in the midwater trawl catches (Table 2). The absence of a small mesh coedend liner in the trawl during the 1980 survey could have led to underestimation of the contribution of small fish, e-g., eulachon (Thaleichthys pacificus), to the species composition. However, in

13

2340 March 6, 1981
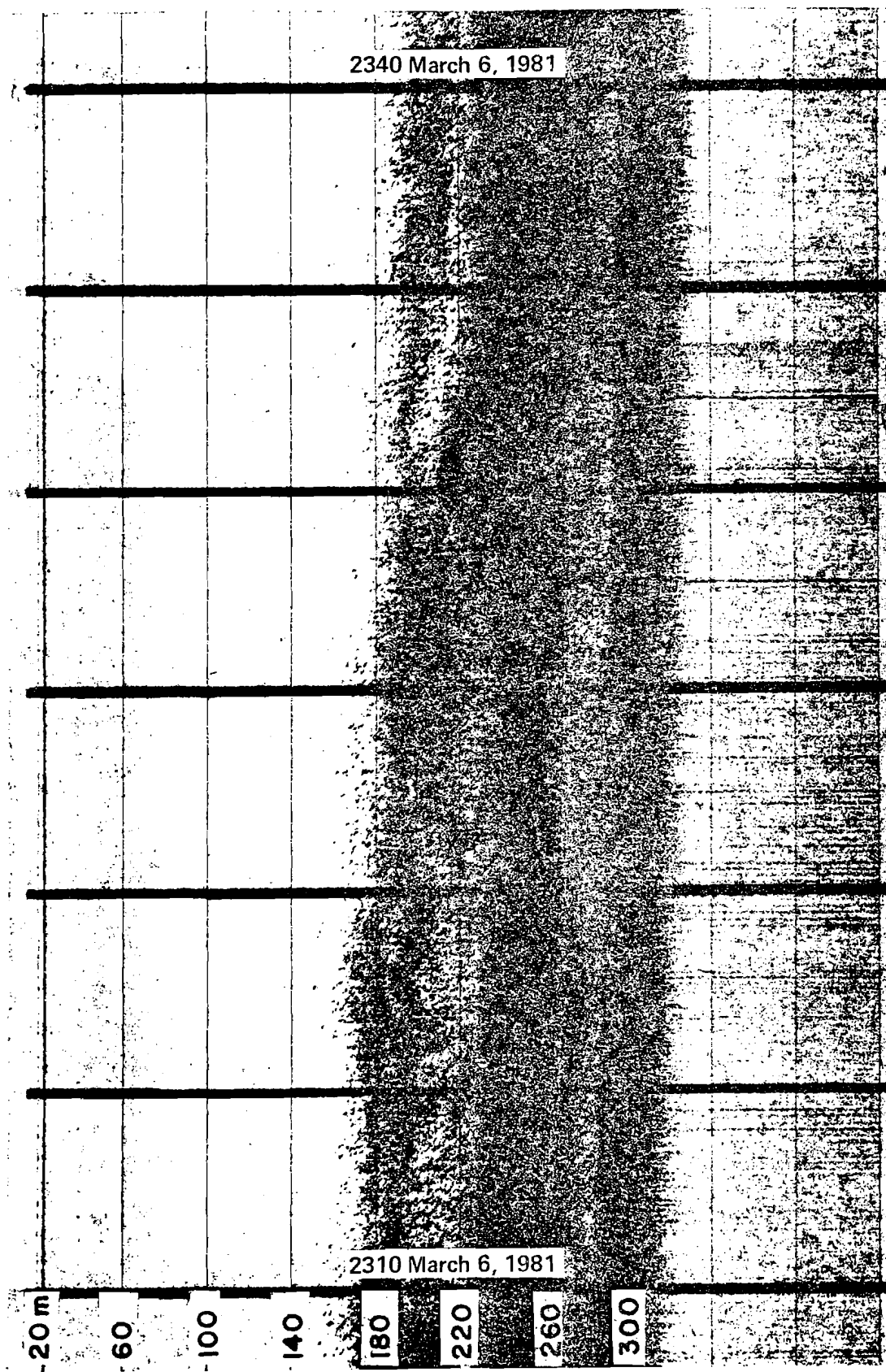
2310 March 6, 1981

20 m
60
100
140
180
220
260
300

Fig. 4.--Echogram of pollock scattering layer.

Table 2. Summary of catch data for midwater trawl hauls made during the 1980 and 1981 surveys in the Shelikof Strait - Chirikof Island region.

|	Survey Periods							
	1980		1981					
	April 2–13		March 2–19		March 27–29		April 7–9	
SPECIES	Total kg	Catch %	Total kg	Catch %	Total kg	Catch %	Total kg	Catch %
Walleye pollock (Theragra chalcogramma)	20,396	97.4	14,245	98.2	7,853	96.9	3,952	98.9
Pacific cod (Gadus macrocephalus)	334	1.6	151	1.0	77	1.0	8	0.2
Eulachon (Thaleichthys pacificus)	108	0.5	38	0.3	75	0.9	20	0.5
Smooth lumpsucker (Aptocyclus ventricosus)	67	0.3	66	0.5	55	0.7	4	0.1
Other	29	0.1	12	0.1	47	0.6	9	0.2
TOTAL	20,934		14,512		8,107		3,993	
No. of hauls	20		13		16		9	

14

1981, when a codend liner was used, eulachon still comprised less than 1% of the total catch by weight, and no other small fish were caught. It should be noted that pollock also constituted over 80%, by weight, of the total catch in bottom trawls.

During each survey, geographic differences in the density of the off-bottom layer of pollock were observed (Pig. 51. Also, temporal changes in the distribution of the pollock concentration were significant during the 5-6 week period it was observed each year. These changes are evident in the results for 1981 (Fig. 5 and Table 3). Between the first and third surveys, there were decreases in the mean density and biomass estimates, but the area inhabited by the pollock aggregation was estimated to have increased by over 75%. Distributional changes in 1980 were apparently similar to those in 1981. Although the off-bottom layer could still easily be detected during the April 1980 acoustic survey, it was significantly less concentrated than when it was first observed in March.

Biomass estimates were not corrected for the inclusion of minor amounts of other species. The point estimate of pollock biomass in 1980 was 709,000 mt (Table 3). In 1980, there was a distinct difference in mean density between the "northern" and "southern" parts of the survey region and separate mean density and biomass estimates were calculated. The "northern" area in Table 3 is the area covered by the most northern eight transects shown in Figure 2. Biomass estimates for the 3 surveys in 1981 were 801,000 mt, 576,000 mt, and 558,000 mt, respectively (Table 3). There is no obvious explanation for the high initial biomass estimate. Because of poor weather, the first survey required substantially more time (13 days) than the others. Also, it was carried out in a south to north direction at a time when there was probably more movement of fish into the Strait then occurred during the subsequent surveys.
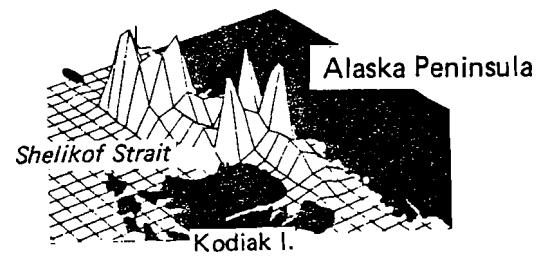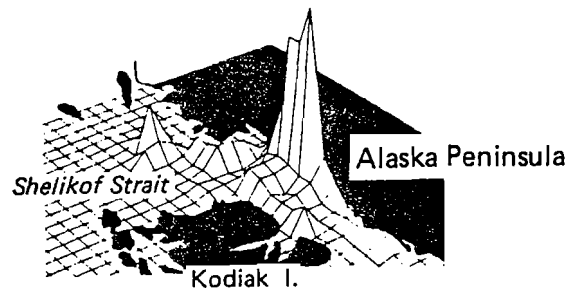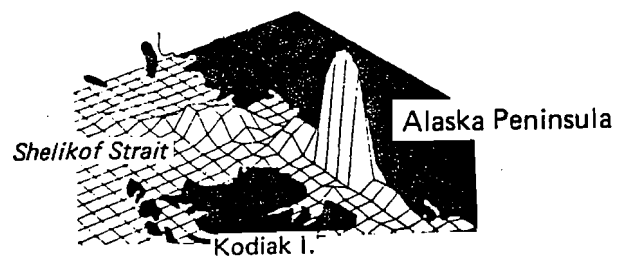
1981
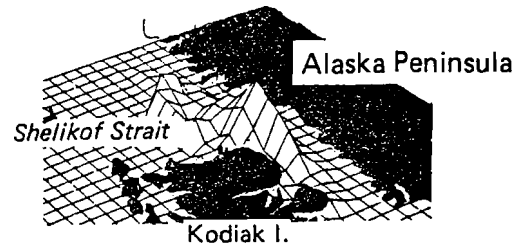
2—14 April

Survey 1
3—15 March

Survey 2
2d—27 March

Survey 3
4—10 April

Fig. 5.--Relative density distribution of pollock during 1980 and 1981 acoustic surveys.

Table 3. Estimates of pollock biomass in the Shelikof Strait - Chirikof Island region determined from acoustic surveys in April 1980 and March and April 1981.

	Mean Density ($\bar{D}$) (kg/1000m²)	SD($\bar{D}$)	Area (km²)	Biomass (mt)	95% C.I. (mt)
1980					
Northern Area	24.8	2.4	4,109	101,851	82,837 - 120,865 ($\pm$ 19%)
Southern Area	77.2	9.2	7,861	607,132	465,443 - 748,821 ($\pm$ 23%)
Total			11,970	708,983	566,024 - 851,942 ($\pm$ 20%)
Survey Dates				**1981**	
March 2-19	116.6	19.8	6,870	801,008	534,397 - 1,067,619 ($\pm$ 33%)
March 24-29	66.5	11.6	8,674	576,455	379,242 - 773,668 ($\pm$ 34%)
April 4-10	45.9	7.9	12,138	557,793	369,848 - 745,738 ($\pm$ 34%)

Size and Age Composition

Length distributions of pollock in the 1980 and 1981 trawl samples are shown in Fig. 6. In the midwater trawl samples from each survey there were two distinct length groups, with modes at approximately 22-23 cm and 35-36 cm. The relative strength of these modes was similar for males and females. However, in 1981 there were significant differences in length composition between surveys. In particular, the relative abundance of the two size groups during survey 2 was different than that observed for surveys 1 and 3. The differences are most likely due to differences between surveys in the distribution and number of trawl hauls (Fig.. 2), rather than changes in the size composition of pollock inhabiting the survey area.

Pollock less than 20 cm in length, which were primarily 10-15 cm (age 1) fish, occurred regularly in the midwater catches. However, they rarely were more than about 5% of the total number of fish in a catch and, of course, were an even smaller percentage of the total weight.

The average size of pollock caught in bottom trawl hauls was distinctly greater than that in midwater samples (Fig. 6). In 1980, a small fraction of the fish in the bottom trawl samples was between 20 and 30 cm, but in 1981, there were negligible numbers of fish in that size range. In both years, pollock < 20 cm were essentially absent in the bottom trawl samples, whereas the older, larger fish (> 35 cm) were consistently more abundant near bottom than in midwater. The lack of pollock < 20 cm in bottom trawl catches is consistent with previous observations, e.g., see Hughes and Hirschhorn (1979).

Estimates of the relative age composition, by weight, of the off-bottom pollock aggregation are shown in Fig. 7. In 1980, 4 and 5 year-old fish, the 1976 and 1975 year classes, were most abundant. These two age groups accounted for 75% of the total biomass. The relative abundance of these two age groups, as well as the low abundance of the 1977 year class as 3 year-olds, is similar to that observed in the fishery in the Chirikof-Kodiak regulatory area in 1980
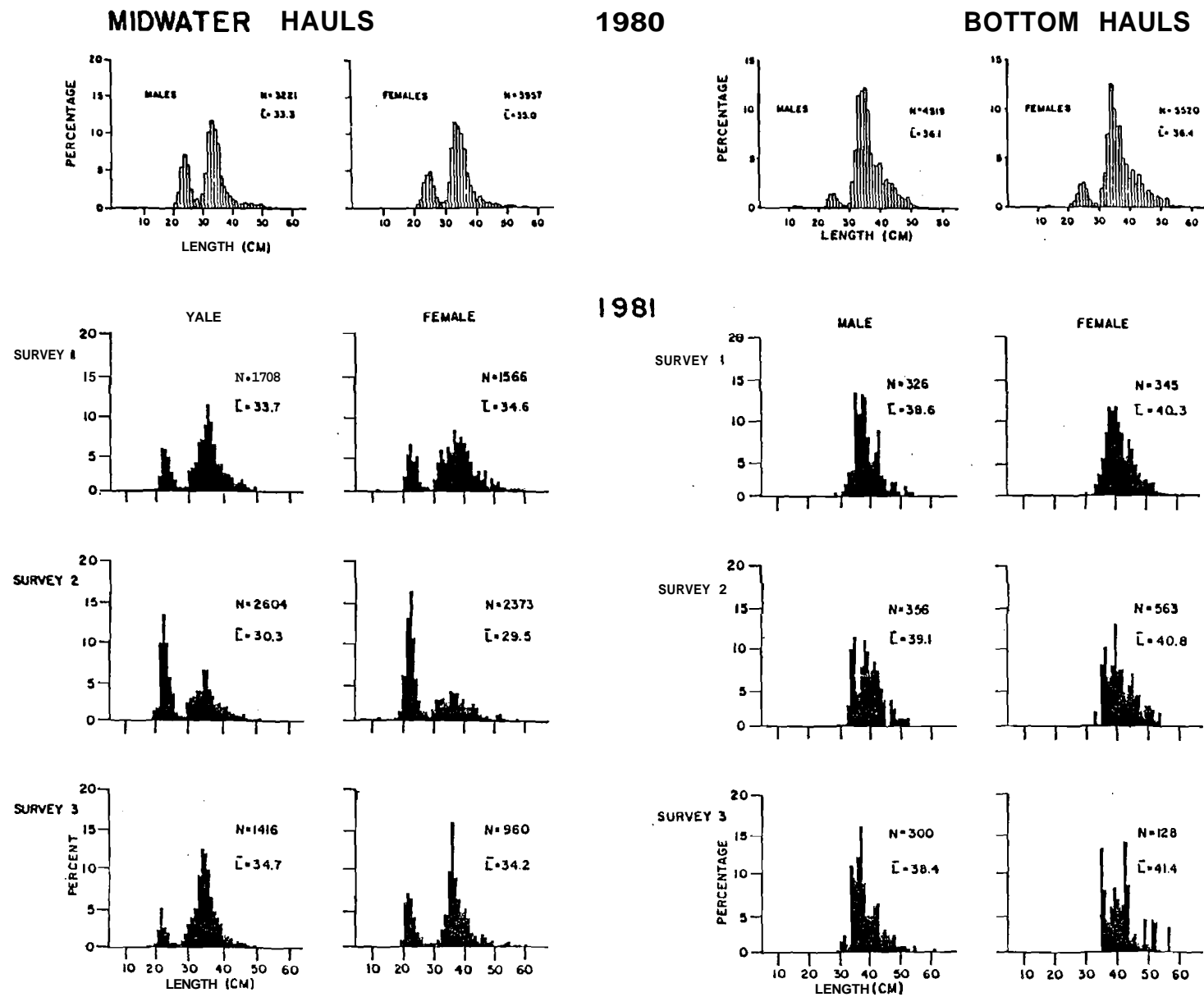
MIDWATER HAULS 1980 BOTTOM HAULS

Fig. 6.--Length distributions, by **sex**, of **pollock** in midwater **trawl** and bottom trawl samples.
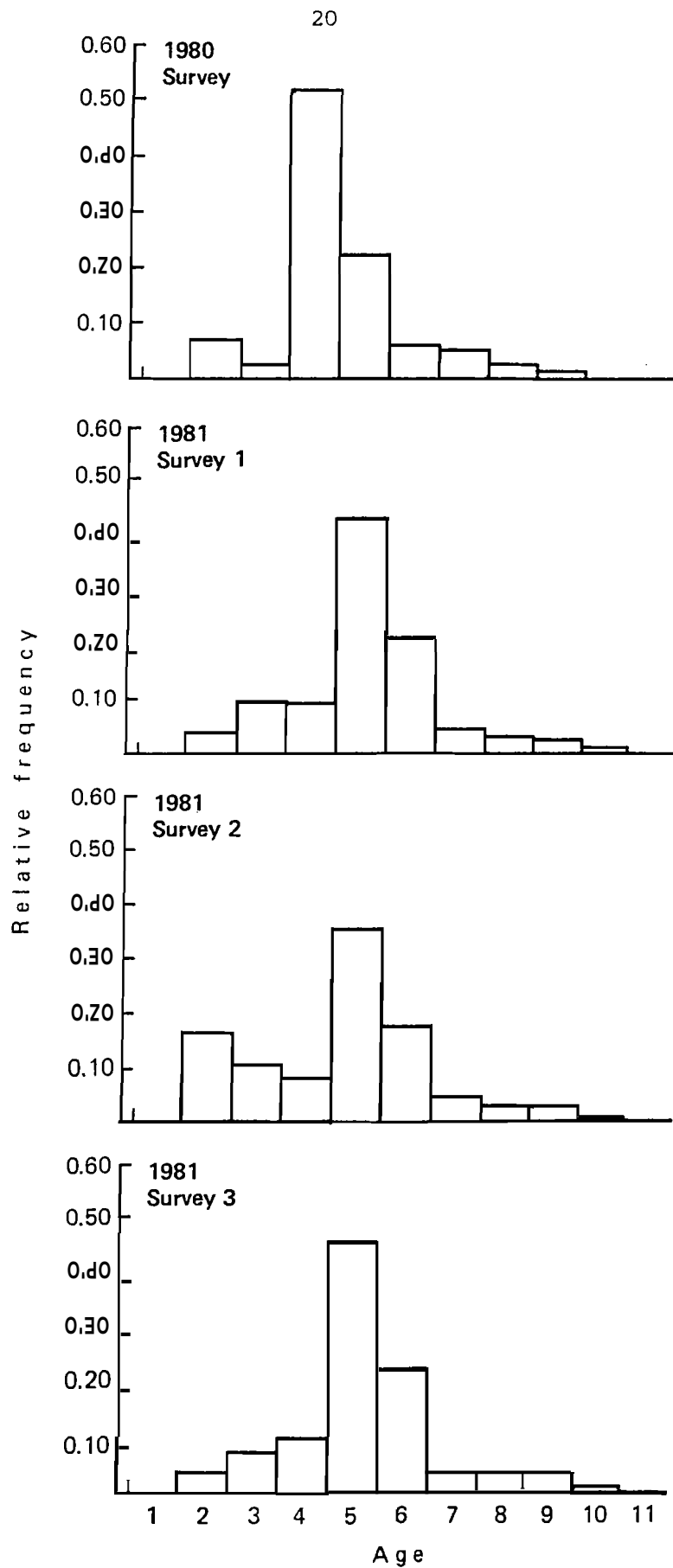
Fig. 7.--Relative age composition (weight) of off-bottom pollock (sexes combined).

(Balsiger and Alton, 1980). The estimated abundance by age in 1981 corresponded with that expected based on the age composition in 1980. The 1976 and 1975 year classes (ages 5 and 6) were again predominant and the 1977 year class (age 4) continued to be a minor part of the stock. The variation in age composition between surveys in 1981 was consistent with the corresponding differences in size composition.

Maturity Composition

Pollock maturity compositions (sexes combined) determined from midwater trawl samples are shown in Fig. 8. A definite progression through maturity stages was observed during the six week period in which the 1981 surveys were completed. The changes in maturity composition between surveys were partially the result of the differences in size/age composition noted previously. However, it is still apparent that there was a pronounced change in the maturity of adult fish, i.e., fish larger than about 30 cm. During the first survey, only a small proportion of fish was classified as spawning and no spent fish were observed. By the time of the second survey, most fish were spawning. Spawning fish were still present during the last survey, but at that time most fish were spent. Although maturity in relation to length and age were not investigated in detail, our observations of these relations basically support those of Hughes and Hirschhorn (1975). They estimated that mean lengths at first maturity for Gulf of Alaska pollock were 29-32 cm for males and 30-35 cm for females, and that both sexes were fully recruited to the spawning population at age 3. They did not encounter any mature 2 year-old females and < 5% of the 2 year-old males they sampled were mature.

The 1981 maturity data show that spawning activity was at a peak about April 1 and abundance data for both years (Fig. 5) suggest that spawning was concentrated in that portion of Shelikof Strait adjacent to the southern end
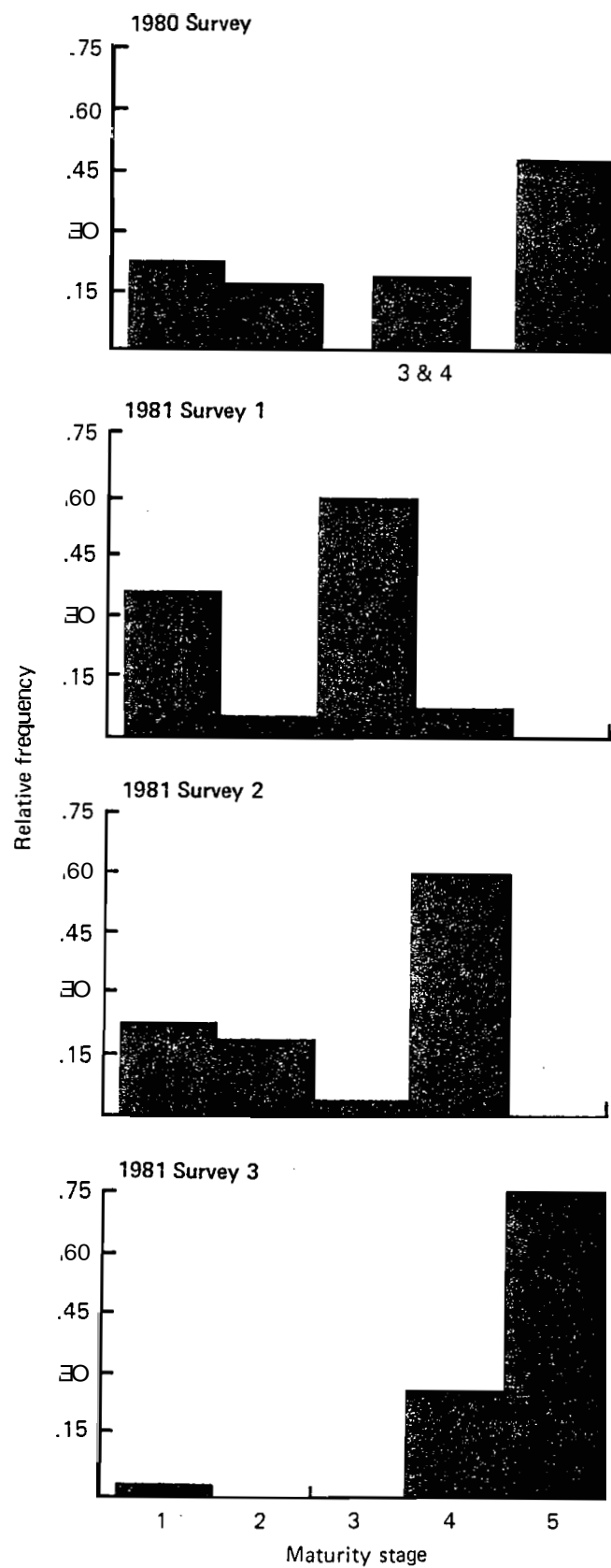
Fig. 8.--Maturity composition (sexes combined) of pollock in midwater trawl samples. See Appendix for maturity stage code.

of Kodiak Island. It is reasonable to suspect that in 1980, within the area in which survey coverage was comparable during both years, the trend in maturity composition with time was comparable to that observed in 1981. The maturity composition for 1980 shown in Fig. 8 includes data from both the area sampled in 1981 and the Chirikof Island-Semidi Islands area to the south (Fig. 2). When the data for the latter area are removed (Fig. 9), the maturity composition shows a higher proportion of spent fish and is more nearly like that observed during the same time (early April) in 1981. Also, it is apparent that the proportion of adult fish in the Chirikof Island-Semidi Islands area samples that were in a prespawning condition was significantly greater than in the area to the north. It appears that maturing fish in that area move north into the Strait for spawning, and this idea is supported by data on the abundance of pollock eggs obtained from ichthyoplankton surveys conducted at the same time as the acoustic surveys (Arthur Kendall, Northwest and Alaska Fisheries Center, personal communication).

DISCUSSION

The 1980 and 1981 acoustic surveys demonstrated that the Shelikof Strait-Chirikof Island region is an important pollock spawning area and provided estimates of abundance that are substantially higher than would have been expected using other survey or fishery information. When compared with either the upper or lower end of the range of total biomass estimates (1.1 to 2.2 million mt) currently considered in managing the fisheries (NPFMC, 1981), the estimates of biomass derived from the acoustic data suggest that a significant proportion of the exploitable pollock population in the Gulf of Alaska was present in the region at the time of the surveys. However, little information is available on the accuracy of the total biomass estimates, except that it is reasonable to assume that the minimum estimate is conservative. The range of total biomass estimates was established from bottom trawl survey
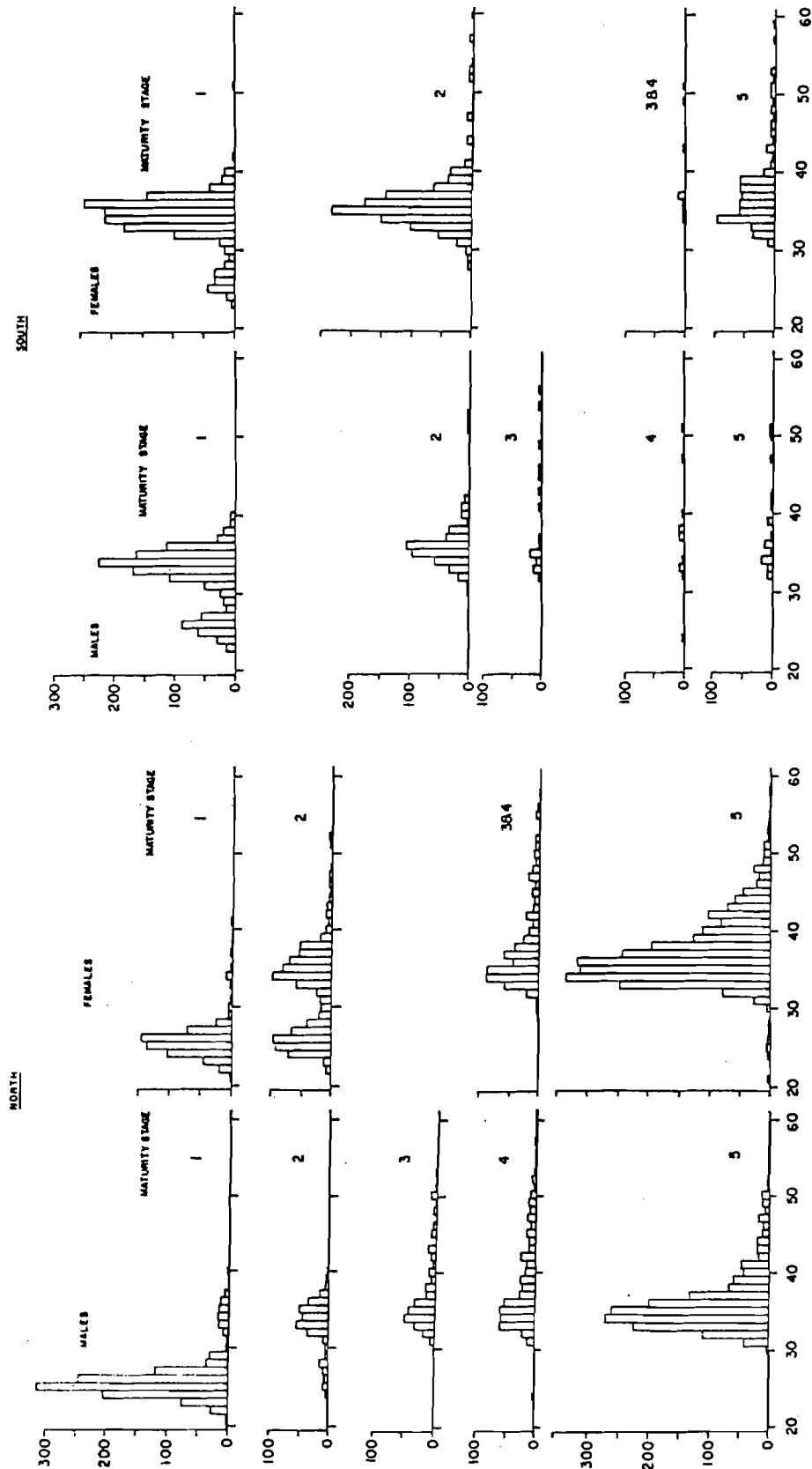
Fig. 9.--Variation in maturity stage, by area, sex and length, for pollock taken in midwater trawl samples during 1980 survey. "South" indicates the Semi Islands-Chirikof area and the data are from trawl stations 188-191 (Fig. 2). "North" indicates the remainder of the survey area. See Appendix for maturity stage code.

data using catchability coefficients of 1.0 and 0.5, and the larger of these two values is undoubtedly too high.

The confidence intervals associated with the acoustic biomass estimates (Table 3) indicate the surveys were capable of reliably detecting changes in abundance of from ± 35% to as low as ± 20%. Because of the continuous distribution of the pollock scattering layer, and also its diel stability, this level of precision was not unexpected. Although the sampling rate was higher in 1980, there is no obvious explanation for the difference in the precision of the 1980 and 1981 estimates. The accuracy of the density and biomass estimates is largely dependent on the bias in the target strength estimate (-31.3 dB/kg) used in scaling the echo abundance data. As mentioned earlier, this estimate is based on results obtained by Traynor and Williamson (1982), and is an average of day and night measurements obtained for non-spawning pollock at relatively shallow depths (50-85 m). Also, the fish were larger (40 to 50 cm) than the average size (30-35 cm) encountered in midwater trawl catches during our surveys. Based on the fact that the target strength/kg estimates reported by Traynor and Williamson increased with decreasing size, the estimate might be considered conservative as a scaling factor. However, no substantive conclusions can be drawn regarding the accuracy of the target strength estimate until in situ estimates are available for spawning pollock and more information is available on how the target strength parameter changes with size and other factors. If it was necessary to base management on the acoustic estimates of biomass obtained in 1980 and 1981, it would be prudent to assume that the target strength/kg value used as a scaling factor was 2 dB low and to adjust the biomass estimates accordingly. Also, of course, as shown by the results for 1981, the biomass estimates could have been significantly affected by the timing and coverage of the surveys, and this problem should

be addressed during any future surveys.

The results of the work in 1980 and 1981 were particularly useful in showing that it may be possible to effectively use late winter-spring acoustic-midwater trawl surveys of spawning pollock concentrations to obtain more reliable estimates of abundance for pollock stocks in the western Gulf of Alaska, as well as to improve on methods used to monitor changes in the abundance and biological condition of the stocks. However, the success of such surveys will depend on how effectively the spatial and temporal distribution of spawning aggregations can be delineated, on the behavior and detectability of these aggregations and knowledge of stock interrelationships. Ichthyoplankton surveys have collected pollock eggs and larvae over a large part of both the Chirikof-Kodiak and Shumagin areas and, although these surveys show that Shelikof Strait is a principal spawning location in the western Gulf, its relative importance as a spawning area is still not well defined (Arthur Kendall, Northwest and Alaska Fisheries Center, personal communication). Another important consideration in conducting surveys during the spawning season is the impact of the frequently severe weather which occurs at that time of year. However, for Gulf of Alaska pollock, this problem is believed to be less important than that presented by the need to survey smaller concentrations of fish over a wider bathymetric and geographic range during the summer (Nelson et al, 1981). Also, acoustic surveys during the spawning season can be directly complemented by ichthyoplankton surveys.

On future surveys, an attempt should be made to refine the allocation of midwater trawl sampling effort in order to better define variation in size and age composition. During the 1980 and 1981 surveys, there was noticeable variation in size composition within the survey area and, although it is difficult to detect, it appears there was a stratification by size within the layer of off-bottom pollock, the smaller (1 to 3 year-old fish) being more abundant in the upper part of the layer.

An especially important requirement for future surveys is determination of the amount of bottom trawl sampling needed to supplement the acoustic and midwater sampling. The level of bottom trawl sampling will depend on whether it will be used only to provide biological data on pollock near bottom which are not sampled by acoustics and midwater trawls, or to also provide estimates of the abundance of the near-bottom component. It appears that, at least initially, better estimates of the abundance of fish near bottom should be obtained. However, it is reasonable to assume that the proportion of the total stock that is near bottom is relatively small. If it is assumed that densities near bottom were not unusually high relative to those in midwater, the results obtained during the 1980 and 1981 surveys support this view. It is also supported by surveys we have conducted for Bering Sea pollock and for Pacific whiting, Merluccius productus, a species with a generally comparable semi-pelagic behavior. These surveys combined independent, but directly complementary, acoustic-midwater trawl and bottom trawl surveys. From the whiting surveys, which were conducted in 1977 (Dark et al, 1980) and 1980 (Nelson and Dark, MS in preparation), it was estimated that only 6% and 12%, respectively, of the total biomass was available to bottom trawls. These percentages could be revised upward based on new whiting target strength estimates, but it is unlikely they would increase by much more than a factor of two. A comparable result was obtained from a summer survey of pollock in the eastern Bering Sea (Bakkala et al, 1982). It was estimated that only 12% of the total biomass of all age groups was available to bottom trawls. However, the off-bottom component of the stock was nearly all juvenile (1 and 2 year-old) fish, while the near bottom component included both juvenile and adult age groups. It should be noted that the estimates of proportions of fish available

to bottom trawls may be conservative since they assume the trawls were 100% efficient in capturing fish available to them.

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Appendix

Maturity stage classification for walleye pollock

Gonad Condition

Maturity Stage	Code	Males	Females
Immature	**1**	Testes thread–like and contained within a transparent membrane.	Ovaries small, transparent and tapered.
Developing	2	Testes uniformly ribbon–like. Surface of testes appear smooth and uniformly textured.	Ovaries tapered, forming two distinct lobes having well developed red blood vessels. Ovaries may be partially granular (some distinct ova).
Mature	3	Testes large and highly convoluted; sperm cannot be extruded. Body wall incision causes testes to be expelled from opening.	Ova distinctly visible but cannot be extruded when ovaries are compressed. Ovaries are two large, distinct lobes. Body wall incision causes gonads to be expelled from opening.
Spawning	4	Testes milk freely or extrude sperm when compressed.	Ova extruded when ovaries are compressed or ova are loose in ovaries.
Spent	5	Testes large, but flaccid, watery and bloodshot.	Ovaries large but flaccid and watery. Ovaries may contain remnants of disintegrating ova and associated structures.